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How to measure the green façade sustainability? A proposal of a technical standard.

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Abstract

Different guidelines drive EU countries to use greening systems – green roofs and green façades - as a sustainable strategy to maximize environmental buildings performance. While technical standards concerning green roofs are available, standards concerning green façades and particularly Living Wall Systems (LWSs) still missing. The paper deals with a research carried out in order to develop a proposal of a technical standard to be adopted as method and tool to measure the performances of green façades and LWSs according to a sustainable approach. The proposal was implemented in consistency to an Italian standard (UNI 11235:2015). The UNI 11235 contains the instructions for designing, building up, monitoring and maintaining the green roofs. Although the standard is not international some basic information may be applied at global scale and most importantly at green façades. The study was focused to setting-up a proper number of requirements to be met in: designing a LWS; defining guidelines for construction stage; monitoring the performance. Requirements and guidelines were set up according to a wide study on international references and thanks to an industrial research project where the authors were involved. Monitoring carried out on chamber tests and on-site was enabled to getting comprehensive data helpful for assessing environmental properties of LWSs and on the whole to characterizing some requirements to be used in the standard.

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Keywords: Living Wall Systems; technical standard; sustainability assessment

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1. Introduction

Nowadays green façades meet the interest of many kinds of stakeholders both in private and public sector.

Green façades are vertical greening systems where usually climbing plants grow along the wall covering it. They include the most recent concept of Living Walls (LWSs), which incorporate vegetation, growing medium, irrigation and drainage into a single technological system, creating a uniform growth along the wall surface.

The Living Walls (LWSs) allow several ecological benefits as proved by scientific studies and articles: Urban Heating Island (UHI) mitigation [1]; indoor pollutants dilution [2]; improvement of envelope energy efficiency both in winter and summer time [3]; noise reduction [4]. Recently to LWS have been recognized other functions. Urban agriculture (e.g. vertical farms) may be assumed as an effective response to social needs occurred due to economic crises. Finally LWSs may have a positive impact on both physical and mental health and wellbeing [5].

Even with the state of the art mentioned proves several ecological and energy benefits such benefits are often: tackled separately, referred to particular climates and studied with different accuracy levels [6, 7].

Furthermore, the LWSs dissemination is constrained by the lack of a framework of rules, regulations and standards.

Currently there are no international technical standards for LWS, despite some policies and guidelines have been developed in several EU countries to encourage green façades construction. However, such initiatives are just limited to few administrations [8, 9, 10, 11, 12]. At the present time there is a twofold difficulty. On the one hand, the technical deficit cannot be matched to economic incentives. As consequence there is a loss of interest by the owners (contrary to what happens for the building retrofit projects, which have been encouraged by taxes reduction correlated to the energy saving potential). On the other hand, entrepreneurs do not have a reference to comply with; thus for most of LWSs a comparison is not feasible.

2. Research and methodology

The research reports a part of the outcomes related to LWSs standardization, deriving from an industrial research project carried out by the authors in cooperation with Growing Green srl, an innovative enterprise (start up) and Politecnico di Torino Spin off specialized in ecofriendly indoor and outdoor LWSs.

The aim of the research was to develop a technical standard proposal for Italy regarding the design, construction, monitoring and maintenance of LWSs. Although the standard is not international some basic information may be applied at global scale.

To achieve this aim the following phases were pursued:

- analyzing standard references and assessment tools related to life cycle approach to: setting-up a proper number of environmental requirements to be met in designing green façades; defining guidelines for construction stage; monitoring the performances;
- analyzing the main international guidelines on LWSs and the national technical standard on greening systems (UNI 11235:2015) to develop the framework and the contents of the proposal.

3. Assessing environmental requirements

The requirements were studied in order to fulfil the largest numbers of environmental aspects over the LWS life cycle (manufacturing, on-site assembling, use and maintenance as well as final disposal).

CEN/TC 350 – “Environmental sustainability of construction works” was used as general framework. With reference to the notion of building life cycle the CEN/TC 350 is one of the main standard available in order both to assess the sustainability aspects of new and existing construction works. The CEN standard includes as reference method the ISO 14040:2006 - Life Cycle Assessment (LCA) and describes a harmonized methodology for assessing the environmental performance of buildings and the life cycle cost performance. Further the standard intends to assess those aspects related to health and comfort of a building.

The environmental requirements are described in the technical standard proposal as a whole (see par. 5). Each environmental requirement is associated to a set of references and assessment tools: standardized tools and rules; new tools fit for LWSs characteristics.

The following paragraph is focused on a specific environmental requirement, related to the indoor air quality, in order to describe the methodological approach adopted to develop new tools.

3.1. A focus on indoor air quality: IAQ monitoring protocols

With regards to scientific studies carried out by NASA in the late ’80s [13] the state of the art emphasizes the plants valuable contribution in terms of “air cleaning” in controlled rooms [14]. Trough photosynthesis, plants enable the Carbon Dioxide (CO_2) absorption. Further most of them have a high potential dilution of Volatile Organic Compounds (VOCs). VOCs are captured by foliage, channeled from stems to roots. Here a metabolic process takes place from bacteria and enzymes. Thus VOCs are no longer dangerous.

The beneficial effects are remarkable. An improved indoor air quality plays a strategic role on occupants’ health. It was demonstrated a reduction of headache and redness of the conjunctivae. It was also proved an enhancement concentration and an improvement of working performance [15, 16].

While a significant number of studies have been carried out on plants pot inside the building [17, 18], few analyses have been brought results concerning the LWSs indoor behavior [19]. One square meter of LWS is generally featured by a high number of plants and by high-density foliage. At the same time the growing medium – that replaces the soil – usually is poor in quantity as well as the bacteria on the roots. Finally, for a full VOCs dilution assessment it must be considered the total amount of materials used for the manufacturing of LWS. Some of them can have absorption properties.

The methodological approach assumed for the LWS’ indoor air quality assessment was based on the UNI EN ISO 16000 standards [20-21]. Such standards refer to building products and finish works. The standards do not consider the connection among “live” materials, particularly the vegetation, and “dead” materials. Thus, a couple of focused analysis tools were implemented in order to adapt the standard requirements to LWSs technology:

- Test cell VOCs monitoring protocol (ProMo_TC)
- Sample room VOCs monitoring protocol (ProMo IAQ)

ProMo_TC (Test Cell Monitoring Protocol) - referred to UNI EN ISO 16000-10:2006 [20] - was divided into two parts.

The Part 1 lays down: the monitoring specific goals; the rules related to UNI EN ISO 16000-10 to be considered in the monitoring; the terms and definitions to be used.

In the Part 2 monitoring is described with accuracy. Particularly the following information needed to be defined:

- Type and category of instruments and related equipment (VOCs sensor, data taker, test cell size and material, etc.).
- Environmental conditions (set point temperature $T = 23°C \pm 2$; relative humidity of $50\% \pm 5$; 12 hours of artificial lighting; air velocity in a range between 0.003 m/s – 0.3 m/s).
- Vegetation acclimation (7 days in test cell with controlled environmental conditions and growing medium saturated of water).
- Test method procedure split up in 5 phases. Phase 1 – quantify background VOCs concentrations from the empty emission test cell, before the start; phase 2 – contaminate the empty emission test cell with a VOC injection, in order to check the air exchange with external air (the test cell should be airtight with no losses); phase 3 – VOC removal; phase 4 - insert the LWS’ test specimen and quantify VOC concentrations; phase 5 - contaminate the emission test cell with a VOC injection and monitoring the removal by plants.

ProMo_IAQ (Indoor Air Quality Monitoring Protocol) is, instead, aimed at assessing the indoor air quality on-site. The protocol collects data about the dilution trend due to vegetation. Temperature, relative humidity, air velocity and air change ratio measurements are even included. Thus, correlations among environmental indoor conditions and thermal conditions are considered. The protocol relates to UNI EN ISO 16000-1:2006 standard [21]. It explains the following procedures:

- Data collection processes. They are about the building features in order to control potential pollutant sources (checking the outside and the inside conditions is required as well as the maintenance procedures and their frequency).
- Building audit techniques to be adopted before monitoring the indoor air (checking of furniture, finishing, HVAC system and air changes).
- Sampling strategy for VOCs, in order to assess the VOCs concentration in indoor air and its variation following the insertion of a vegetated wall.

ProMo_TC and ProMo IAQ protocols were validated trough the R&D activities of the Growing Green srl. The Growing Green LWSs - featured by easy assembly modular boxes, thin, lightweight and ecofriendly - were used. (Fig.1).

a

b

Fig. 1. (a) Modular boxes in the nursery; (b) Indoor Living Wall System, Asti, Italy (courtesy of Growing Green).

The monitoring was carried out with a sensor aimed at assess the total VOCs in ppm. The air samples were analyzed in a test cell (with a unit of 1 m^3 of air) and in a couple of same sized office rooms, one containing modular boxes shaped with vegetation and the other not (floor surface = 18 m^2; volume = 50 m^3; glazed surface on north façade = 13 m^2; used by 2 employers for 8 hours per day; air-conditioned 8 hours per day). In test cell was monitored one square meter of vegetated panel - with a mix of three plant species (Lonicera, Bergenia, Heuchera) - while in the office rooms were used two square meters of vegetated panels.

These activities have allowed to develop the final version of the protocol thanks to their application to real cases, although the monitoring is still ongoing.

Both protocols are assumed as references in the technical standard proposal, with regards to the Environmental requirements chapter.

4. Guidelines and technical standard analysis on vertical greening systems

4.1. International LWSs Guidelines

On the basis of the international review, 5 guidelines on vertical greening systems were analyzed (Tab. 1). The selected guidelines include a set of information about: benefits; typologies; design; installation; maintenance; plant selection; case studies.

Table 1. International guidelines selected.

State	City	Title
Australia	Melbourne	Growing Green Guide [22]
Republic of Singapore	Singapore	A concise guide to safe practices for vertical greenery [23]
France	Paris	Végétalisation des murs et des toits [24]
United Kingdom	-	UK Guide to Green Walls [25]

Many topics are tackled in the guides and systematized in benefit and technical sections.

The benefit section examines the environmental requirements of green walls and façades at the following scales: urban scale (urban heat island effect mitigation, absorption of particulate matters, enhancement of biodiversity, etc.), building scale (noise pollution insulation, heating and cooling energy demand reduction, Volatile Organic Compounds dilution, etc.) and human health (psychological and physical health). In most cases, experimental testing and/or computer modelling based on experimental data are used.

The technical section provides advice on the factors that need to be considered to design, construct and maintain green walls and façades.

These topics were useful for the formulation of the technical standard proposal.

4.2. UNI 11235:2015 technical standard

In Italy the Law n. 10/2013 "Regulations for the development of urban green spaces" recognizes the importance of vegetation in the built environment and therefore the need to increase public and private green areas, considering also vertical greenery [26].

In the last years some municipalities (Firenze, Brescia, Carugate, Genova) have introduced in their building codes some guidelines aiming at promoting the use of vegetation on buildings' walls, in order to reduce summer heat gain due to the solar radiation [27,28,29,30]. However, such initiatives are just limited to few administrations; none of the examined cases considers the use of more innovative technologies such as LWSs. Moreover, there are no support policies or economic incentives to encourage vertical greenery.

The national standard UNI 11235:2015 provides technical requirements regarding the design, construction and maintenance of green roofs [31], but its equivalent for green walls is still lacking.

In development of LWS standard described hereinafter, the national standard UNI 11235:2015 was assumed as main reference. LWS and green roof technologies have many similarities such as the ecological requirements and the environmental requirements. Similarities between LWS and green roof were taken into account in several stages: design, construction and maintenance.

The new standard proposal introduces supplementary regulations and technical specifications concerning the LWSs features.

5. Results and discussion

The methodology adopted has allowed to develop a complete framework of information and to structure them into the technical standard proposal.

The proposal, in step with the international guides and the Italian standard UNI 11235:2015, has been divided into 8 chapters covering the following areas:

- Significance and Use
- Scope
- Definitions
- Environmental requirements
- Project and design
- Construction and monitoring
- Maintenance
- References

The intended use of this standard proposal is to provide technical information to practitioners in the fields of LWS design and construction. The standard encourages innovative and responsible LWS design.

Users of this guide include: planners, developers, architects, landscape architects, engineers, general contractors, subcontractors, owners, facility managers, financial organizations related to building industry, building materials and product manufacturers, public administrations, and other building professionals.

With reference to LWS typology, the proposal refers to following LWSs: 1) continuous; 2) modular; 3) light; 4) heavy. Thus all the possible technological solutions currently available on the market are included.

The standard introduces technical specifications concerning:

- Indoor LWSs placed in controlled environment [20-22 °C] over the year. They are similar in all the geographical areas
- Outdoor LWSs subjects to the climate and microclimate. They can be threatened by environmental variations and attacks from parasites

According to CEN/TC 350 – "Environmental sustainability of construction works", the standard proposal identifies the environmental requirements to be assumed as references in the whole building process, including the following stages: manufacturing, on-site assembling, use and maintenance, end of life.

Each environmental requirement is associated to a set of references and assessment tools; on the one hand standardized tools and rules; on the one other new tools fit for LWSs characteristics. For example, to assess the indoor air quality ProMo_TC and ProMo _IAQ, described in the paragraph 2.1, are assumed as a reference.

On the whole 40 requirements were identified: 12 associated with manufacturing stage, 4 with on-site assembling stage, 18 with use and maintenance stages, 6 with final disposal stage (Tab. 2).

…..Table 2. Examples of environmental requirements.

MANUFACTURING
Reducing the number, the weight and the thickness of materials and elements
Maximizing the use of low environmental impact materials
Maximizing the use of products with a plurality of functions
Maximizing the use of products with a similar expected life (…)
ON-SITE ASSEMBLING
Maximizing the use of easy-assembling connections
Maximizing the use of easy-installing products
Maximizing the use of integrated and operable devices for water, fertigation and electrical needs (…)
USE AND MAINTENANCE
Selecting plant species with low maintenance needs
Maximizing the use of products characterized by easy-transportation, construction and maintaining
Selecting products with high environmental performance: thermal, acoustic, indoor air quality (…)
END OF LIFE
Maximizing the use of products based on reverse assembling technologies
Maximizing the use of reusing/recycling products (…)

Furthermore, the standard proposal describes requirements and materials related to the design process (e.g. data concerning the framework for LWS anchorage, the growing medium, the vegetation, the irrigation system, etc.). Technological details for a proper LWS design are even encompassed.

The standard also identifies general strategies for proper installation.

A detailed maintenance plan is part of the proposal. In particular, the standard highlights the need to drawing up (by manufacturer) a use and maintenance guide, according to LWS typology. The guide is aimed at maintaining the efficiency of LWSs over a long period.

The guide provides technical advices concerning: the frequency of maintenance; the maintenance of plant species (regular pruning, remove foliage wastes, etc.); the maintenance of the irrigation devices (check of nutrient levels, growing medium moisture content).

The proposal can be assumed as a significant basis for a broader research activity in order to develop a new national technical standard to measure the LWSs performance.

6. Conclusion

Architecture is recognized as an important element of European culture and of the environment in which Europeans live. Even though LWSs are energy efficient and environmental friendly and they are enable to fulfill a broad number of sustainable needs, their diffusion in the construction market is still weak. Despite benefits are decisive some constrains needed to be overcome.

In particular, while for green roofs are available European and National harmonized standards and regulations, those concerning LWS are missing. Thus the difficulty of encouraging any kind of recommendation or introduction of proper requirements in sustainability specifications as well as in building codes.

The paper highlights the key role that might play a technical standard focused on LWSs.

A reference standard could lead to a wider recognition in public/private partnerships. Such connotation would result an improvement in market access and tax benefits depreciable over a defined period.

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